R&D and Market Structure: The Impact of Measurement and Aggregation Problems

Alfred Kleinknecht
Bart Verspagen

ABSTRACT. Estimates on the relationship between concentration and R&D effort are shown to be sensitive to problems of aggregation and of adequate measurement of R&D in small firms. While estimates from the official R&D survey of the Netherlands show a highly significant linear relationship between concentration and R&D, comparable estimates from our R&D data base prove it to be insignificant. However, at a finer level of disaggregation and when our sample is split into sectors with low and high technological opportunities, we discover evidence of a quadratic relationship in the latter and evidence of a weak linear relationship in the former.

Schumpeter's hypothesis that market power is conducive to innovation has attracted substantial amounts of research. However, in the recent literature, indications have been given that the actual importance of market power for innovation performance might be quite modest, and, in any case, less than proportional to the enormous attention it received in the literature.

It seems that at least some of the explanatory power of market structure is lost, once one controls for other variables such as differences in technological opportunity between industries, buyer (as opposed to seller) concentration, diversification, profitability, advertising-to-sales ratios, etc. (Baldwin and Scott, 1987). For example, in a study by Scott (1984) evidence of an inverted U relationship between market power and R&D completely disappeared, or, in a paper by Levin, Cohen and Mowery (1985) the importance of market power decreased dramatically, when controls for differences across firms and industries apart from seller concentration were introduced.

In all those studies, the reliability of the available R&D data has been taken for granted. In this paper we do not intend to estimate more complex models as has been done, e.g. by Hughes (1986), Lunn and Martin (1986), or the above-quoted authors. Rather we restrict ourselves to simply demonstrate that problems related to the measurement of a key variable in such models, i.e. R&D, might have a considerable impact on the issue.

In a recent contribution to this Journal, Kleinknecht (1989) reported results from a large-scale innovation survey in the Netherlands. It was argued that there are considerable amounts of small-scale and often informal R&D work in small enterprises which are not captured in the R&D survey by the Dutch Central Statistical Office, and that similar shortcomings might hold for R&D surveys in other OECD countries. Such measurement differences do not relate to some percentages but to orders of magnitude of R&D in small and medium-sized firms (see also Van Dijk and Kleinknecht, 1984; Kleinknecht, 1987a).

The underestimation of R&D in small firms might be a source of bias when investigating the influence of firm size and market structure on R&D. The influence of a slightly different, i.e. simplified measurement of R&D on the relation-

Final version accepted on June 19, 1989

SEO, Foundation for Economic Research of the University of Amsterdam
Jodenbreestraat 23
1011 NH Amsterdam
The Netherlands

and

Maastricht Economic Research Institute on Innovation and Technology (MERIT)
P.O. Box 616
6200 MD Maastricht
The Netherlands

Small Business Economics **1**: 297—301, 1989.

ship between firm size and innovation was discussed in Kleinknecht (1989). In this paper we try to assess its impact on the relationship between market structure and R&D effort.

Since we find relatively more R&D in small firms, we expect industrial sectors in which small firms play an important role to appear more R&D-intensive in our survey than in the official survey. To a certain extent, the relative importance of small and medium-sized firms might be (negatively) reflected in measures of market power. This leads us to the hypothesis that the relationship between R&D and indicators of market concentration is likely to be weaker (i.e. slopes of regressions should be less steep) when comparing regressions from our survey with those from the official R&D survey.

Due to the cooperation of the R&D Department of the Dutch Central Statistical Office we are able to present comparable cross-section regressions of R&D on market power based on our own R&D figures as well as on those from the official survey.[1] Both R&D data sets relate to R&D man-years in 1983 in 41 sectors, covering the entire Dutch manufacturing industry. The R&D intensity is defined as the percentage share of R&D man years in total manpower.

As a measure of concentration, we use in all regression equations the Theil entropy coefficient (ENTROPY) as measured in 1981 by the Central Statistical Office (Ten Cate and Sprangers, 1984).

The Entropy coefficient is defined as follows:

$$\text{ENTROPY} = \sum_{i=1}^{n} x_i \ln\left(\frac{1}{x_i}\right) \qquad (1)$$

where n is the number of enterprises in an industry and x_i is the share of an enterprise in its industry's employment. Note that ENTROPY is an *inverse* measure of concentration, i.e. the higher the concentration, the smaller is ENTROPY (Ten Cate and Sprangers, 1984, p. 12). Hence, a positive impact of concentration on R&D is indicated by a negative sign of the regression coefficient. The results from various regression specifications are given in Table I.

It can be added that in addition to the regressions in Table I, regression equations including a quadratic term were also estimated. However, these proved to be insignificant.

TABLE I

Regressing R&D-intensity (RDI) on market power (ENTROPY) in Dutch manufacturing industries (t-values in brackets)

(A) Estimates from the official survey:	
(1a) RDI = 5.58 − 0.60 ENTROPY; (2.759)	$\bar{R}^2 = 0.163$; $n = 41$
(1b) ln RDI = 2.68 − 0.46 ENTROPY; (5.111)	$\bar{R}^2 = 0.400$; $n = 41$
(B) Estimates from our survey:	
— if manufacturing is broken down into 41 sectors:	
(2a) RDI = 2.17 + 0.035 ENTROPY; (0.205)	$\bar{R}^2 = 0.001$; $n = 41$
(2b) ln RDI = 0.60 + 0.002 ENTROPY; (0.029)	$\bar{R}^2 = 0.000$; $n = 41$
— if manufacturing is broken down into 63 sectors:	
(3a) RDI = 4.01 − 0.217 ENTROPY; (1.59)	$\bar{R}^2 = 0.02$, $n = 63$
(3b) ln RDI = 1.16 − 0.080 ENTROPY; (1.84)	$\bar{R}^2 = 0.04$, $n = 63$

The regressions on the official survey data show a significantly positive linear relationship between the degree of concentration and R&D, confirming the original Schumpeter hypothesis. However, the regressions from our survey do not. It should be noted that the standard errors of regression coefficients are of the same magnitude. However, the slope of the regression line in our data reduces to zero, which we ascribe to our capturing of more R&D in small firms.

Regressions (1a), (1b), (2a) and (2b) were run at a relatively rough level of aggregation, distinguishing between 41 manufacturing sectors only. This was required because the R&D data from the official survey did not allow for a finer disaggregation. Fortunately, our data allow handling at a finer level, distinguishing 63 sectors.

Equations (3a) and (3b) in Table I estimate the relationship between R&D-intensity and the Theil entropy coefficient for 63 sectors. They show that the level of aggregation indeed matters: As opposed to equations (2a) and (2b), equations (3a) and (3b) give weak support to a linear relationship between market power and R&D-intensity, the t-value being significant at 90% level in equation (3a), and, in equation (3b), covering the loglinear case, the t-value is even significant at 95% level. Here again, we do not document the regression equations with quadratic terms which proved to be insignificant. It should be noted that regression coefficients in equations (3a) and (3b), although (weakly) significant, are still more than two standard errors lower than the estimates from the official R&D survey in equations (1a) and (1b) of Table I.

We also examined the possibility of a quadratic relationship (i.e. of an inverted U-curve) between market structure and R&D in high technological opportunity sectors. In doing so, we met the problem that we had no unambiguous criteria for classifying our 63 sectors by "high" and "low" technological opportunity. Nonetheless, in terms of Standard Industrial Classification Codes, we made the following (rough) division of our 63 sectors:

"traditional" sectors: 201—273, 321—349, 374, 390—399.
"modern" (high technological opportunity) sectors: 280—313, 350—384 (with the exception of 374).

This distinction is based on qualitative judgment from historical innovation research.[2] An application of the Chow test (see Johnston, 1984, pp. 207—225) proved that this distinction indeed improves the regression estimates. In the traditional sectors, we again found no evidence of a quadratic relationship. However, there is (weak) evidence of a linear relationship in the traditional sectors as can be seen from equations (4a) and (4b) in Table II.

Table II shows that the opposite holds for the modern sectors: while we found no evidence of a purely linear relationship, equations including a quadratic term proved to be significant at a 90% level (see equation (5a)), and the same equation on logs of R&D-intensity is significant even at a 97.5% level (see equation (5b)).

Maximizing equation (5a), we obtain an entropy value of 4.0, and in equation (5b), the maximum is 4.2. Since the entropy values of all sectors vary between 0.03 and 10.13, we can conclude that the highest R&D-intensities are observed at a degree of concentration that is slightly above average. Ten Cate and Sprangers' comparison of C-4 concentration ratios and Theil coefficients in the Netherlands shows that both measures of market power are highly correlated ($r = 0.95$) and that Theil values of 4.0—4.2 roughly correspond with a C-4 concentration ratio of 50—55% (1984, 14). This implies that there is an interesting parallel between our and Scherer's finding that, in general, a moderate degree of market power may be most conducive for innovation:

> . . . technological vigor appears to increase with concentration mainly at relatively low levels of concentration. When the four-firm concentration ratio exceeds 50 or 55 percent, additional market power is probably not conducive to more vigorous technological efforts, and may be downright stultifying (1984, p. 247).[3]

Unfortunately, we cannot do comparable estimates on the R&D data from the official survey, since the latter are available only at the rougher aggregation level of 41 sectors, in which case only 11 "modern" sectors can be distinguished.

In conclusion, we can say that estimates on market structure and R&D effort are indeed sensitive to measurement and aggregation problems. The capturing of greater amounts of small-

TABLE II
Regressing R&D-intensity (RDI) on market power (ENTROPY) in traditional and modern sectors (t-values in brackets)

(A) traditional (low technological opportunity) sectors:

(4a) $\mathrm{RDI} = 1.91 - \underset{(1.69)}{0.069}\ \mathrm{ENTROPY}$; $\bar{R}^2 = 0.04$, $n = 42$

(4b) $\ln \mathrm{RDI} = 0.59 - \underset{(1.54)}{0.046}\ \mathrm{ENTROPY}$; $\bar{R}^2 = 0.03$, $n = 42$

(B) modern (high technological opportunity) sectors:

(5a) $\mathrm{RDI} = 3.48 + \underset{(1.16)}{1.357}\ \mathrm{ENTROPY} - \underset{(1.36)}{0.169}\ \mathrm{ENTROPY}^2$; $\bar{R}^2 = 0.01$, $n = 21$

(5b) $\ln \mathrm{RDI} = 1.08 + \underset{(1.84)}{0.300}\ \mathrm{ENTROPY} - \underset{(2.31)}{0.035}\ \mathrm{ENTROPY}^2$; $\bar{R}^2 = 0.19$, $n = 21$

scale R&D in our survey leads to estimates which differ from directly comparable estimates on the official R&D data: While linear as well as log-linear regression estimates on the official data give strong support to a positive relationship between market structure and R&D (with t-values of 2.7 and 5.1), comparable estimates (at the same aggregation level) on our data prove it to be insignificant throughout (see Table I). However, at a finer level of aggregation ($n = 63$ instead of $n = 41$) we find a weakly significant linear relationship between R&D and market power. It should be added that in the latter case, regression coefficients prove to be significantly lower than those in the official R&D survey. Moreover, a rough splitting of our 63 sectors into "traditional" and "modern" sectors reveals a (weak) linear relationship in the former and a quadratic relationship in the latter. In general, regressions on logs of R&D-intensities show higher significance levels than regressions on original values.

As a qualification, it should be reminded that it still remains to be seen whether the relationships documented in our above equations will persist if additional variables were included. Moreover, the above results crucially depend on two topics: First, the reliability of our (qualitative) classification of industry sectors into "modern" (high technological opportunity) sectors and "traditional" (low opportunity) sectors; secondly, and probably more importantly, the credibility of our results does depend on the reliability of our alternative R&D survey.

In 1984, the Netherlands introduced a government subsidy to R&D which was designed to support R&D in small and medium-sized firms. Meanwhile, figures on numbers of small enterprise establishments applying for R&D subsidies have become available (BOT, 1988, p. 15). Although, for a number of reasons, these figures are not strictly comparable with our data, they clearly suggest that our estimates on the numbers of small firms performing any R&D work (Kleinknecht, 1987a, p. 31) are likely to be more realistic than the figures from the official survey.

It can be added that we also feel endorsed by independent findings in Italy which have recently been published. From their survey on innovation, Archibugi *et al.* report that there must be more than three times as many firms performing R&D than are reported in the official Italian R&D survey (1987, p. 140). This comes close to our estimates for Dutch manufacturing industry. It also supports our view that steps need to be taken in order to arrive at a more adequate measurement of R&D in small and medium-sized firms.

Acknowledgement

Our research was supported by the Dutch Ministry of Economic Affairs. We wish to thank an anonymous referee of this journal for valuable comments on an earlier version of this paper. Responsibility for the contents is solely with the authors.

Notes

[1] We are indebted to thank Hans Kolfoort from the R&D Department of the Central Statistical Office of the Netherlands for kindly estimating a number of cross-section regressions from their R&D data, which, by reasons of confidentiality, are not published at the same level of sectoral disaggregation that is handled in this paper.

[2] In a rough generalization, the "traditional" sectors might be characterized as 19th century sectors, while "modern" sectors have been largely generated (or rejuvenated) during the 20th century (Kleinknecht, 1987b, ch. 8).

[3] It should be emphasized that our finding of an inverted U curve relates exclusively to what we classified as "modern" sectors. Scherer's above quotation, however, applies to *all* sectors, although he found a significant quadratic relationship only in the case of what he considered as "traditional" sectors.

References

Archibugi, Daniele, Sergio Cesaratto, and Giorgio Sirilli, 1987, 'Innovative Activity, R&D and Patenting: The Evidence of the Survey on Innovation Diffusion in Italy', in *STI REVIEW* (OECD), No. 2, September, 135—150.

BOT, 1988, *Beleidsoverzicht technologie* (A report on technology policy by the Dutch Ministry of Economic Affairs, in Dutch), 's-Gravenhage 1988.

Hughes, Kirsty, 1986, *Exports and Technology*, Cambridge: Cambridge University Press.

Johnston, J., 1984, *Econometric Methods*, 3rd ed., New York: McGraw-Hill.

Kleinknecht, Alfred (with the assistance of Hans Bieshaar, Aat Keet, Jos den Ronden and Bart Verspagen), 1987a, *Industriële innovatie in Nederland. Een enquête-onderzoek* (Industrial Innovation in the Netherlands. A Postal Survey, in Dutch), Assen: Van Gorcum.

Kleinknecht, Alfred, 1987b, *Innovation Patterns in Crisis and Prosperity. Schumpeter's Long Cycle Reconsidered* (with a

Foreword by Jan Tinbergen), London: Macmillan and New York: St. Martin's Press.

Kleinknecht, Alfred, 1989, 'Firm Size and Innovation. Observations in Dutch Manufacturing Industry', *Small Business Economics* **1**(3), 1—8.

Levin, Richard C., Wesley M. Cohen, and David C. Mowery, 1985, 'R&D Appropriability, Opportunity and Market Structure: New Evidence on Some Schumpeterian Hypotheses', in *American Economic Review. Papers and Proceedings* **75**(2), 20—24.

Lunn, John and Stephen Martin, 1986, 'Market Structure, Firm Structure and R&D', *Quarterly Journal of Economics and Business* **26**(1), 31—44.

Scherer, F. M., 1967, 'Market Structure and the Employment of Scientists and Engineers', *American Economic Review* **57**(3), 524—531.

Scherer, F. M., 1980, *Industrial Market Structure and Economic Performance*, 2nd ed., Chicago: Rand McNally.

Scherer, F. M., 1984, *Innovation and Growth*, Cambridge: MIT Press.

Scott, John T., 1984, 'Firm Versus Industry Variability in R&D Intensity', in Z. Griliches (ed.), *R&D Patents and Productivity*, Chicago: The University of Chicago Press, 233—245.

Ten Cate, A. and A. H. Sprangers, 1984, 'Concentratie en deconcentratie in de industrie (1976 and 1981)' (Concentration and de-concentration in industry, in Dutch), in *Sociaal-economische maandstatistiek (Supplement)*, No. 7, Voorburg: CBS.

Van Dijk, J. W. A. and Alfred Kleinknecht, 1984, 'De positie van kleine en middelgrote ondernemingen in het Nederlandse innovatiebeleid' (The position of small and medium-sized enterprises in Dutch innovation policy, in Dutch), in *Economisch Statistische Berichten*, Vol. 69, No. 3474, September, 894—899.